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Beam Energy Scan – Phase I Results:

- Seen the turn-off of QGP signatures.
- Seen suggestions of the first order phase transition.
- Not seen conclusive evidence of a critical point.

# The most promising region for refining the search is in the lower energies → 19.6, 15, 11.5, 7.7, and lower.

The iTPC Upgrades strengthen the BES II physics program, and enables new key measurements:

- Rapidity dependence of proton kurtosis
- Dilepton program (sys. errors and intermediate mass region)
- Enables the internal fixed target program to cover 7.7 to 3.0 GeV

#### The STAR Upgrades and BES Phase II

inner TPC

upgrade

Endcap TOF



#### Major improvements for BES-II

#### **iTPC Upgrade:**

- Rebuilds the inner sectors of the TPC
- Continuous Coverage
- Improves dE/dx
- Extends η coverage from 1.0 to 1.5
- Lowers  $p_T$  cut-in from 125 MeV/c to 60 MeV/c

#### EndCap TOF Upgrade:

- Rapidity coverage is critical
- PID at  $\eta$  = 0.9 to 1.5
- Improves the fixed target program
- Provided by CBM-FAIR

#### Event Plane Detector

#### EPD Upgrade:

- Improves trigger
- Reduces background
- Allows a better and independent reaction plane measurement critical to BES physics



## What is the Current TPC?





- 24 sectors
- 12 on each side
- Large pads for good dE/dx resolution in the Outer sector
- Small pads for good two track resolution in the inner sector



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- Staggered readout
  - Only 13 maximum possible points
    - Issues in Tracking: recognition and resolution
  - Only reads ~20% of possible gas path length
    - Inner sectors essentially not used in dE/dx
- Essentially limits TPC effective acceptance



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## Pad plane



- Increase coverage. Higher density FEE
- Prototype has been produced and tested





#### BES Phase II – Relationship to TPC Upgrade



Basic performance improvements

The TPC inner sector upgrade is important for three reasons:

- 1) It extends the accessible rapidity range
- 2) It reduces the low  $p_t$  cut-in threshold
- 3) Improves dE/dx resolution

4) Also Improves the momentum resolution

# Simple Geometry $\rightarrow \eta$ acceptance





## Do we have any such low p<sub>T</sub> tracks?

60 MeV/c tracks Not found

120 MeV/c 125 MeV/c track This is an actual event

160 MeV/c tracks

# Increased rapidity coverage



Increased efficiency for  $|\eta| < 1$  mostly due to lower  $p_T$  cut-in values Increased efficiency for  $|\eta| < 1.5$  mostly due to tracks exiting the end cap



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#### Additional Tracks Available for Physics



11.5 GeV		Total	Standard TPC	Inner Upgrade	p <sub>T</sub> < 60 MeV/c
	Pions	234	152	+17%	18%
η <0.5	Kaons	25.3	12.4	+30%	4%
	Protons	34	26	+10%	6%
	Pions	435	283	+21%	
η <1.0	Kaons	47	22.9	+35%	
	Protons	66	50	+13%	
	Pions		<20%	90%	
1.0<  <b>η</b>  <1.5	Kaons		<20%	80%	
	Protons		<20%	90%	1

#### Improvements to dE/dx



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# **iTPC** Physics

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### Statistics Needed in BES phase II



Collision Energies (GeV):	7.7	9.1	11.5	14.5	19.6
Chemical Potential (MeV):	420	370	315	260	205
Observables	Ν	1illions o	<u>f Events</u>	Needec	
$R_{\rm CP}$ up to $p_{\rm T}$ 4.5 GeV	NA	NA	160	92	22
Elliptic Flow of $\phi$ meson ( $v_2$ )	100	150	200	300	400
Local Parity Violation (CME)	50	50	50	50	50
Directed Flow studies $(v_1)$	50	75	100	100	200
asHBT (proton-proton)	35	40	50	65	80
net-proton kurtosis (κσ <sup>2</sup> )	80	100	120	200	400
Dileptons	100	160	230	300	400
Proposed Number of Events:	100	160	230	300	400

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QGP

1<sup>st</sup> P.T.

С. Р.

EM Probes

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# **Elliptic Flow**



Elliptic flow results are improved



# **Directed Flow**





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## **Directed Flow**





# **Directed Flow**



The added reach of the iTPC allows a significant measurement of v1 for most centralities



# **Rapidity Density Widths**





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# **Fluctuation Analysis**





Published STAR results for beam energy dependence of  $\kappa\sigma^2$  (top panels) and  $S\sigma/Skellam$  (lower panels for net protons in Au+Au collisions. The left panel illustrate the effect of  $p_T$ selections while the right panels indicate the effects of rapidity selections



# **Fluctuation Analysis**





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0.8

## **Di-lepton program**



 The dominate systematic error on the di-electon experiment is the purity of electrons. The added pad-rows will improve dE/dx



The expected purity for electrons as a function of transverse momentum.



Di-electron program in the Intermediate mass region is now possible with the iTPC



The expected systematic uncertainty of dielectron excess mass spectrum with the iTPC upgrade compared to the current TPC case



# Fixed Target Program

Collider Energy (GeV)	Fixed-Target Energy	Center-of-mass Rapidity
62.4	7.7	2.10
39	6.2	1.87
27	5.2	1.68
19.6	4.5	1.52
14.5	3.9	1.37
11.5	3.5	1.25
9.1	3.2	1.13
7.7	3.0	1.05

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### Target Design 2014 and 2015



#### **Target design:**

Gold foil 1 mm Thick ~1 cm High ~4 cm Wide 210 cm from IR

2014: Passive tests2015: Beams steered to target





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#### Run 14 and 15 Setup

STAR



# **Identifying Target Events**



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STAR



#### Au + Au Fixed Target 4.5 GeV



- May 20<sup>th</sup> 2015 Test run with lowered beam
- 1.25 millions triggers, ~100k central events



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# **iTPC** Pictures

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### Strong back



#### Prototype – original drawings



Only modify position of FEE openings.No reduction in thicknessPure construction project, noengineering and designbut lots of retrieving old knowledge.



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### Electronics



- FEE based on current FEE, but using ALICE SAMPA chip
- Twice channels per FEE
- RDO similar to existing
- Developments over several years by BNL electronics group



RDO prototype



Pre-prototye iFEE (ppFEE) electronic card shown plugged into the padplane

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## Work in Shandong

 Prototype work ; going through all the steps of assembly, winding, gluing and testing





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# Sector Insertion Tooling



- Concept based on ALICE design
- Cartesian coordinates



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# Sector Insertion Tooling



 Sector Installation Platform – It is a platform that consists of extension slides that brings the sector manipulation tool into the position for the sector to be installed in the end-wheel.



# Conclusions



- iTPC improves the reach of all BES II observables
- iPTC brings significant new physics
  - Radipity dependence of net-proton kurtosis
  - Di-electron program in the Intermediate mass region
  - Internal fixed target program covering 7.7 to 3.0 GeV
- The prospect of getting E-TOF for BESII will also be a boost for the physics.
- The project has made significant progress and has a dedicated team – for both and data analysis



# **Backup Slides**



# **Simplified Production Plan**

- Pad planes at BNL
- Strong backs at UT and/or commercial
- Joining of strong back and pad planes at LBNL
- Wire-winding, mounting at Shandong
- Insertion tooling at BNL
- FEE and RDO, DAQ at BNL



## Path forward

- Proposal has been updated since submitted in Feb. New version is now available
- It was realized that project cannot be done for below 2M, and that the insertion tooling is a critical item and should be included
- Review BNL DOE summer fall 2015
- Most production in FY17,18 important procurements in FY16



#### Planned Cost to DOE

WBS		FY15	FY16	FY17	FY18	Conting	Total
1	Mgt	92.0	180.5	185.9	125.9	111.5	695.7
2	Electronics	53.3	602.8	38.9	727.8	268.3	1,691.1
3	Mechanics	70.4	423.4	381.4	4.9	173.6	1,053.6
	Insertion						
4	tooling	58.0	406.2	82.8	0.0	106.1	653.1
5	Installation	0.0	0.0	0.0	0.0	0.0	0.0
			1,612.				
	Total DOE	273.7	8	688.9	858.6	659.4	4,093.5

## Wire arrangement



 A sub group has studied wire arrangements to optimize pad layout and looked at ways to reduced grid leak



Figure 36: The original STAR pad plane geometry (side view). The outer sector pad rows covered the entire pad plane but the inner sector pad rows were widely spaced (> 5 cm).



Figure 37: The new STAR pad plane geometry. The outer sector configuration remains the same, but the inner sector has more pad rows and there aren't any gaps between the pad rows.

# Elliptic Flow of the phi meson



![](_page_46_Figure_0.jpeg)

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![](_page_47_Figure_0.jpeg)

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# Au + Al Results: Spectra and ratios

Paper has been signed off by the working group. Ready for God Parent Committee

![](_page_48_Figure_2.jpeg)

Spectra fit with Bose-Einstein Functions

Ratios fit with Coulomb Functions

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#### Pion Ratio and Coulomb Potential Comparison

![](_page_49_Figure_1.jpeg)

Paper has been signed off by the working group. Ready for God Parent Committee

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![](_page_50_Figure_0.jpeg)

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## The Inner Sector Pads are too small

- The <u>outer</u> sector pad size was chosen to match the diffusion limit of P10
  - Width (pitch) in the outer sector is 6.7 mm
  - Tonko has measured an average of 3 pads hit per cosmic ray track
- The inner sector pads were deliberately made smaller (for no good reason except that people expected it, HW)
  - Width (pitch) in the inner sector is 3.35 mm
    - note different pad plane to anode wire spacing & gain (2 mm vs 4 mm)
  - Tonko has measured an average of 4 pads hit per cosmic ray track
- It seems quite reasonable to increase the size of the inner sector pads so that an average of 3 pads are hit per cosmic ray track
  - Note, this does not mean 6.7 mm pitch is best ... due to different gain and wire geometries in the inner and outer sectors
  - Real simulations are required ... but Outer subsector:

![](_page_51_Figure_11.jpeg)

![](_page_52_Picture_0.jpeg)

![](_page_52_Figure_1.jpeg)

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## TPC Sector Detail – Aging of the Anode Wires

![](_page_53_Picture_1.jpeg)

![](_page_53_Picture_2.jpeg)

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- Gating Grid
- Ground Shield
- Anode
  - 4 mm pitch, no field wires
  - Spacing: inner  $\neq$  outer

#### • Pad Plane Sector Operation for 20:1 signal to noise

Sector	anode voltage	gas gain
inner	1170	$3770\pm10\%$
outer	1390	$1230\pm10\%$

![](_page_53_Figure_11.jpeg)

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### Pad Size: Constraints & possibilities ... (numbers, not science)

![](_page_54_Picture_1.jpeg)

- The outer sectors are 6.7 mm x 20 mm (pitch)
- The inner sectors are 3.35 mm x 12 mm (pitch)
- The full range of possibilities for the new inner pad plane
  - Height from 12 mm to 20 mm (nb: 0.5 mm gap on all edges)
    - Note: only 12, 16 and 20 mm match anode wire spacing (3x, 4x, 5x)
  - Width from 3.35 to 6.7 mm
- Translate to number of electronic channels
  - 6,650 channels if 3.35 by 12 mm (50 rows)
  - 2,000 channels if 6.7 by 20 mm (30 rows)
    - Currently 1750 channels in 13 rows (widely spaced at ~5 cm)
  - Range is from 1 to 4x number of channels (for hermetic coverage)
    - 1x would accommodate 6.7 x 20 pad pitch
    - 2x would accommodate 4.8 x 16 pad pitch
    - 3x would accommodate 4.2 x 12 pad pitch

(ror reference, ALICE uses 4x7 pads, but note that Neon-CO2 has better diffusion characteristics so we expect smaller pads in their case)

Optimize this number for performance cost and engineering factors Horizontal dimension will be determined by physics and engineering

(87% coverage, 30 rows)

Limited choices in the vertical dimension

(100% coverage, 40 rows)

(100% coverage, 50 rows)

# Implications for dE/dx

![](_page_55_Picture_1.jpeg)

![](_page_55_Figure_2.jpeg)

- ~1.5σ K-π, 2.5σ p-π: 1σ K-p for p>5 GeV/c
- Has gotten better since then: now more like 6%
- Need TOF for K-p in the region 2-4 GeV
- Scales as 1/VL: with 130-180 cm, more like <5.5% everywhere
  - Something like 1.5σ K-p